Seafood Watch
Seafood Report

MONTEREY BAY AQUARIUM®

Farmed Shrimp

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Worldwide Overview
(Excluding Mexico and Thailand)

Final Report
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About Seafood Watch® and the Seafood Reports

Monterey Bay Aquarium's Seafood Watch® program evaluates the ecological sustainability of wild-caught and farmed seafood commonly found in the United States marketplace. Seafood Watch defines sustainable seafood as species, whether fished or farmed, that can exist into the long-term by maintaining or increasing stock abundance and conserving the structure, function, biodiversity and productivity of the surrounding ecosystem. Seafood Watch® makes its science-based recommendations available to the public in the form of regional pocket guides that can be downloaded from the web (www.montereybayaquarium.org) or obtained from the program by emailing seafoodwatch@mbayaq.org. The program's goals are to raise awareness of important ocean conservation issues and to shift the buying habits of consumers, restaurateurs and other seafood purveyors to support sustainable fishing and aquaculture practices.

Each sustainability recommendation in the regional pocket guides is supported by a Seafood Report. Each report synthesizes and analyzes the most current ecological, fisheries and ecosystem science on a species then evaluates this information against the program's conservation ethic to arrive at a recommendation of "Best Choices", "Proceed with Caution" or "Avoid". In producing the Seafood Reports, Seafood Watch seeks out research published in academic, peer-reviewed journals whenever possible. Other sources of information include government technical publications, fishery management plans and supporting documents, and other scientific reviews of ecological sustainability. Seafood Watch Fishery Analysts also communicate regularly with ecologists, fisheries and aquaculture scientists, and members of industry and conservation organizations when evaluating fisheries and aquaculture practices. Capture fisheries and aquaculture practices are highly dynamic; as the scientific information on each species changes, Seafood Watch's sustainability recommendations and the underlying Seafood Reports will be updated to reflect these changes.

Parties interested in capture fisheries, aquaculture practices and the sustainability of ocean ecosystems are welcome to use Seafood Reports in any way they find useful. For more information about Seafood Watch® and Seafood Reports, please contact the Seafood Watch program at Monterey Bay Aquarium by calling 831-647-6873 or sending an email to seafoodwatch@mbayaq.org.

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Table of Contents

Introduction to Series on Shrimps

This is Volume III in a series of three seafood reports covering the shrimps most frequently found in West Coast markets and restaurants.

Index:

General Shrimp Biology

Shrimps belong to the order Decapoda, a crustacean order that also includes the lobsters, true crabs and hermit crabs. All decapods possess a full carapace or "head shield" and, eponymously, five pairs of walking legs [1]. Their first three pairs of thoracic appendages are modified into "maxillipeds" or feeding legs [2].

Shrimps are distinguished from the other decapods by having the front-most section of the abdomen about the same size as the rest of the sections and by having five pairs of abdominal appendages, or pleopods, adapted for swimming [1].

There are more than 3,000 living species of shrimp worldwide [2]. Many are tiny or inhabit niches unsuited to mass harvest [1]. Those harvested on a commercial basis share two characteristics: they are relatively large, roughly 2–10 cm carapace length, and they school, shoal, migrate toward baited traps, or otherwise aggregate so that they are amenable to capture. Worldwide, about 40 species of shrimp meet these criteria and are harvested commercially [3]. About ten species have been raised in captivity; for some species, such as the Pacific white shrimp, *Penaeus vannamei*, selective breeding is developing truly domesticated breeds of shrimp.

Scientific Names and Shrimp vs. Prawn

While there is no hard and fast rule about applying the names “shrimp” and “prawn” (Watling 2004; Shumway 2003), certain scientific references state that "shrimp" refers to the infra-order Caridea, which includes the widely harvested coldwater genera *Pandalus* and *Crangon* [2]. With more than 2,000 species, these so-called "true shrimp" [2] are the largest group of shrimp-like decapods [2]. They are distinguished by the fact that small side flaps of the exoskeleton overlap on their first, second, and third abdominal segments [2]. Under this definition, "prawn" refers to members of the infra-order Penaeidea, which includes the penaeids or tropical shrimp [2]. Also known as the "primitive shrimp", prawns are recognizable because their first and second anterior segments are about the same size (Figure 1) [2].

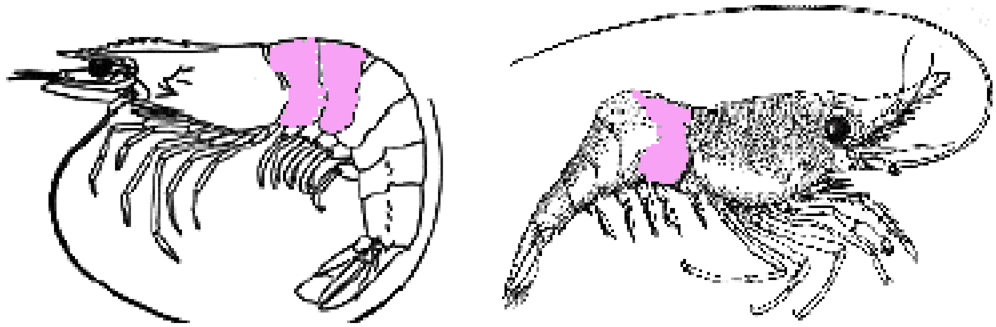


Image after Museum Victoria, Australia [1].

However, there is vast confusion among the common names of these animals. The "spot prawn" *(Pandalus platyceros)* of the U.S. West Coast is actually a shrimp [2, 3] while in British usage only the genus *Palaemon*, with its prominent head spine or rostrum, can be called a prawn [1].
In U.S. markets, "shrimp" is the default name for all these animals. "Prawn" often refers to freshwater shrimp or large saltwater shrimp. The term "scampi" refers not to a species but to a cooking method: any large shrimp cooked in butter and garlic [4]. Commercially harvested shrimp may be divided into three categories based on their habitat: coldwater or northern species; warmwater, tropical, or southern species; and freshwater species [4].

Market Overview
The market for shrimp continues to expand, and farmed shrimp supply an ever-increasing share of that market. About three-quarters of world shrimp production is wild-caught, 70% from warm waters and 30% from cold waters. The remaining quarter of total production is farm-raised shrimp [5, 6]. However, wild shrimp tend to be consumed in the country where they are caught, while farmed shrimp are more likely to be traded internationally (Clay 2003). Perhaps 50% of shrimp traded internationally are farm-raised (Clay 2003).

With worldwide shrimp fisheries at or near maximum sustainable yield, any growth in shrimp production must come from farm-raised shrimp. Many nations are turning to farm-raised shrimp as an attractive source of international trade revenue. In 2003, one study found that shrimp farming is growing at 12% to 15% per year (Clay 2003; Rosenberg 2003).

According to the latest available figures from 2003, about 87% of the U.S. shrimp supply was imported. This includes farmed and wild, warm and coldwater-shrimp. The U.S. national import statistics do not distinguish between these categories (NMFS Statistics 2003).

Executive Summary

Several species of saltwater shrimp and one freshwater prawn are being cultivated in captivity. Farming methods range from simple ponds located in coastal areas to high-tech inland systems that filter and recirculate their water. The vast majority of farmed shrimp comes from economically disadvantaged tropical nations, including India, Thailand, Indonesia, Ecuador, China, Bangladesh, and Vietnam. In many areas, shrimp farming has had an adverse effect on coastal habitat, water quality and local village economies. Shrimp are also farmed in the southern United States, with more regulatory oversight than is common in most other nations. In the United States and elsewhere, experimental farms are in the process of developing methods for low-impact shrimp culture. As of the latest figures available in 2003, about 87% of the U.S. shrimp supply was imported. This includes farmed and wild, warm- and coldwater-shrimp, with very little way for the consumer to discern them. It is hoped that the advent of country-of-origin labeling (COOL) in autumn 2004 will help U.S. consumers discern the sources of their shrimp.

Shrimp farmed in Mexico and Thailand has been evaluated in more depth in separate Seafood Watch reports, which can be found at www.montereybayaquarium.org.

Overall Seafood Ranks:

International Farmed Shrimp (general recommendation): Avoid

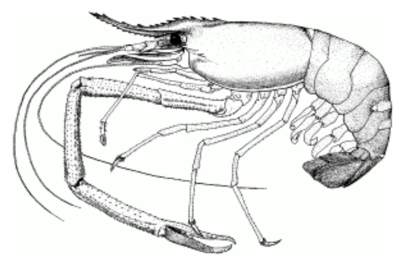
List of Component Ranks	Low Conservation Concern	Medium Conservation Concern	High Conservation Concern	Critical Conservation Concern
Feed Efficiency		√		
Risks to Wild Stocks		√		
Disease Transfer		√		
Habitat Effects			√	
Pollution		√		
Chemical Use		√		
Management Effectiveness			√	

U.S. Farmed Shrimp (general recommendation): Proceed with Caution

List of Component Ranks	Low Conservation Concern	Medium Conservation Concern	High Conservation Concern	Critical Conservation Concern
Feed Efficiency		√		
Risks to Wild Stocks	√			
Disease Transfer	√			
Habitat Effects		√		
Pollution		√		
Chemical Use	√			
Management Effectiveness		√		

FARM-RAISED SHRIMP
Worldwide Overview


Figure 1. Top left: Black tiger prawn, *Penaeus monodon.* Illustration ©Monterey Bay Aquarium. Top right: Pacific white shrimp, *Penaeus vannamei.* Photo© South Carolina Institute of Scientific Inquiry. Below: Freshwater prawn, *Macrobrachium rosenbergii.* Illustration courtesy UN FAO FIGIS database.



Shrimp is an enormously popular seafood in the developed nations of the world, including the United States, the European Union, Japan, and Australia. In the United States, shrimp recently surpassed canned tuna as the seafood most consumed per capita [5]. Unlike canned tuna, however, shrimp remains a luxury product in the developed world, commanding prices of six to eight dollars per pound for the farmer [7]. In Asia, a shrimp farm can offer 50 times the annual return of rice farming (Clay 2003). Tropical nations can raise three or more crops of warmwater shrimp per year (8; Clay 2003), making shrimp farming an attractive source of foreign exchange for developing nations. Even within developed nations, farmers searching for a profitable product respond to the lure of shrimp. In some communities in the southern U.S., displaced fishermen have turned to shrimp farming as a way to continue making a living on the coast [8].

Several species of shrimp are now being farm-raised (Table 1). Because of their quick growth and large size, warmwater penaeid shrimp have been the focus of aquacultural production [4, 9]. The Asian black tiger shrimp *Peneus monodon* reaches harvest weight of 35 grams after 120 days and is widely cultivated in the Eastern Hemisphere [9]. In the Western Hemisphere, including the United States, farmers focus on the Pacific white shrimp, *Penaeus vannamei* [9]. In Asia, other penaeids are favored. There has also been interest in farming shrimp in fresh water--this would open the possibility of shrimp farming to many inland areas that do not enjoy a ready supply of sea water. The long-clawed freshwater prawn *Macrobrachium rosenbergii* has been farmed experimentally in the Pacific basin and the U.S. [7], although these shrimp are aggressive with each other and require a culture method that allows each adult its own hiding place [7]. Some penaeid species, among them the Pacific white shrimp *Penaeus vannamei*, the Chinese white shrimp *P. chinensis*, and the black tiger prawn *P. monodon*, can adapt to water much less saline than seawater [7, 10, 11]. This allows raising of shrimps in non-seawater systems---often in groundwater. These penaeid species are not aggressive, can be cultured at high densities, and have become the mainstay of shrimp farming worldwide [9].

Life History

Most shrimps are omnivorous, catching or scavenging whatever plant or animal material is readily available. The intestine runs the dorsal length of the abdomen; it is the brown line sometimes called the "mud vein" on cooked shrimp. Like other arthropods, shrimps have no internal skeleton, being protected instead by a chitinous exoskeleton which must be repeatedly shed as the animal grows [1]. The sexes are separate, and females tend to be larger than males. Some species release their eggs into the water column, while others brood the fertilized eggs on the female's abdomen until hatching. Newly-hatched shrimp larvae bear little resemblance to their elders; each must undergo up to 12 molts to attain final form as a juvenile shrimp. The tiny shrimp larvae drift with the plankton, where they are important food for many fishes and invertebrates [1]; those that escape predators and find favorable currents may live long enough to reproduce.

Pandalid shrimps such as the spot prawn may live for three to seven years [12, 13]; in contrast, many of the warm-water penaeid shrimps complete their life cycles in one to three years [14]. Figure 2 shows the penaeid life history that is typical of the natural life cycle of many farm-raised shrimp species.

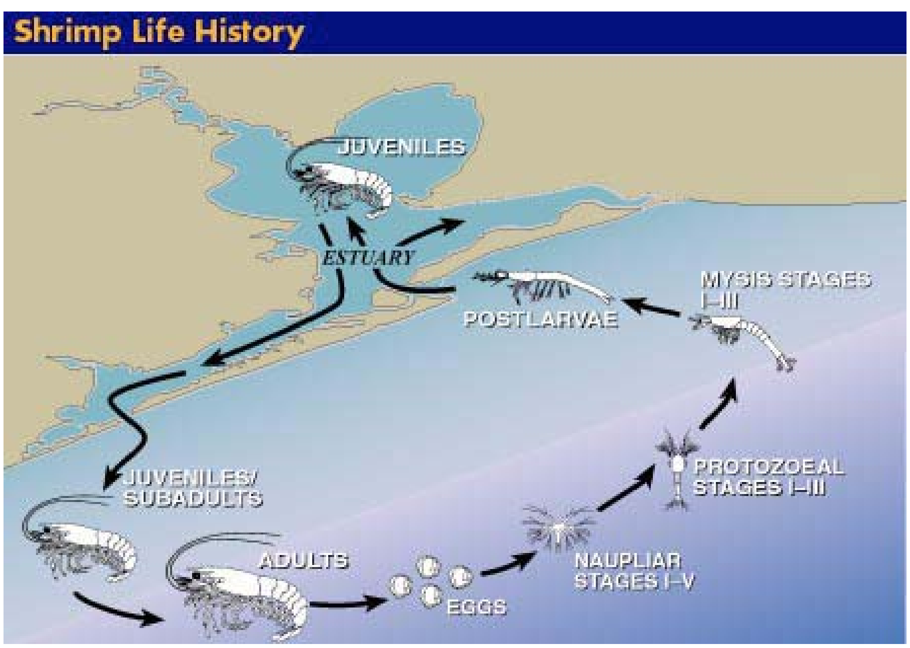


Figure 2. Typical penaeid shrimp life cycle. Image after Benfield and Downer, 2001 [15].

Scientific Name	Common name(s)	Where farmed	Percentage of total world farmed shrimp production [9]
Saltwater shrimp–major species			
Penaeus monodon	black tiger shrimp, tiger prawn	Asia, Indonesia, Australia	47%
Penaeus vannamei	white shrimp, Pacific white shrimp, Vanna White	North and South America, Caribbean	16%
Peneus chinensis	white shrimp, Chinese white shrimp, fleshy prawn	Asia (tolerates cooler water than other penaeids)	14%
Penaeus stylirostris		North and South America, Caribbean	**
Penaeus japonicus		Asia; some South America	**
Penaeus penicillatus		Asia, Indonesia, Australia	**
Saltwater shrimp–minor species			
Penaeus schmittii *P. semiculcatus* *P. brasiliensis* *P. paulensis* *P. setiferus* *P. subtilis* *P. duorarum* *P. occidentalis* *P.californiensis*			**
			** all together total 23%
Freshwater species			
Macrobrachium rosenbergii	freshwater prawn, long-clawed prawn	Asia, U.S. (experimental)	
P. vannamei	Pacific white shrimp	U.S. (experimental)	
P. monodon	Black tiger shrimp	Thailand (experimental)	

Table 1. Shrimp species in aquaculture.

Statement on the Availability of Science

Because shrimp farming can be highly lucrative, many studies of farming methods are available in peer-reviewed journals and from universities and agricultural extension programs. Studies of the environmental impacts of shrimp farming have been produced since the early 1990's. In 1999, the Global Aquaculture Alliance, an international coalition of shrimp producers and marketers, published a monograph entitled Codes of Practice for Responsible Shrimp Farming (GAA 1999). In 2001, at least two peer-reviewed journals published extensive reviews of shrimp farming practices and their environmental impacts worldwide [16, 17], and a monograph was published on the same subject [18]. Extensive work on shrimp farming has been published by the Shrimp Farming and the Environment Consortium, a group made up of the World Bank, U.N. Food and Agriculture Organization, World Wildlife Fund, and NACA (Clay 2003).

Market Information

It is important to note that, in the United States, the various species of shrimp are generally sold interchangeably, traded not by species, but by *size*. It matters little to most restaurateurs whether their breaded shrimp is *Penaeus setiferus* or *Pandalus jordani*, as long as it's the right size. I n the United States, farmed and wild-caught shrimp enter the same market and are traded interchangeably [5].

The Shrimp Count

Because shrimp are so small, they are sold by a count (number) per pound rather than by individual weight (Table 2) [19]. This is expressed as a range. For example, a 16/20 count means it takes 16 to 20 shrimp of that size to make up a pound [19]. The smaller the count, the larger the shrimp.

Size Name	Green headless	Peeled	Cooked
Extra Colossal	Under 10	Under 15	16/20
Colossal	Under 15	16/20	21/25
Extra jumbo	16/20	21/25	26/30
Jumbo	21/25	26/30	31/35
Extra large	26/30	31/35	36/40
Large	31/40	36/45	41/50
Medium large	36/40	41/45	46/50
Medium	41/50	46/55	51/60
Small	51/60	56/65	61/70
Extra small	61/70	66/75	71/80
Tiny	Over 70		

Table 2. Shrimp count per pound. From Seafood Business Seafood Handbook, 1999.

Market Names

Perhaps more than any other seafood commodity, the market names of shrimp are seldom standardized. Several different species are commonly called "white shrimp", and the situation is the same for "pink shrimp", "rock shrimp", and "tiger shrimp" [4], [20], [21]. Moreover, widely-distributed species have many common names. As one example, the circumpolar species *Pandalus borealis* may be marketed as pink shrimp, northern shrimp, Alaska pink shrimp, northern pink shrimp, Pacific pink shrimp, or salad shrimp [22;3].

Seasonal Availability

In the United States, demand for shrimp is greatest during the winter holiday season, which, in terms of shrimp consumption, means Thanksgiving in late November, Christmas in December, and Superbowl Sunday in early January (Clay 2003). The availability of farmed shrimp is greatest in the autumn, as farms in many temperate areas harvest a single yearly crop September or October and then close down for the winter [8]. Tropical shrimp farms may harvest more than one crop per year, but even these tend to bring a crop to market in time for the winter holiday season, further increasing the shrimp supply from November through January (5; Clay 2003). This abundant supply tends to push wholesale shrimp prices down [5].

Shrimp is scarcest in the early spring (late January through early March), when many northern fisheries are closed for the winter, temperate farms have yet to re-open, and tropical farms are still growing out their first new crop [8, 23]. Spring is when shrimp wholesalers expect the highest prices for their products [5].

Product Forms

Not only are there many varieties of shrimp for sale worldwide but there is a great diversity in product forms. Product can be divided into two basic types: raw and cooked [19]. It can then be further divided into fresh and frozen [19]. Within these broad categories, almost all shrimp sold in the U.S. market is sold as head-off tails, and the bulk of that is sold frozen [19]. Primary product forms for frozen shrimp are (Figure 3):

Green Headless: The standard market form. Includes the six tail segments, with vein, shell and tail fin. "Green" does not refer to shell color but to the uncooked, raw state of the shrimp. Also called "shell-on" or "headless" [19].

Peeled: Green headless shrimp without the shell [19].

PUD: Peeled, un-deveined, tail fin on or off; raw or cooked. The vein, running the length of the tail, is the intestine, also called the mud vein or sand vein [19].

Tail-on Round: Undeveined shrimp with tail fin on [19].

P&D: Peeled, deveined, tail fin on or off; raw or cooked. Another name for IQF P&D shrimp is PDI (peeled, deveined, individually frozen) [19].

Cleaned: Shrimp that is peeled and washed, a process that removes some or all of the vein but is not thorough enough to warrant the P&D label [19].

Shell-on Cooked: Cooked tail, with vein, shell and tail fin [19].

Split, Butterfly, Fantail: Tail-on shrimp that are cut deeply when being deveined [19].

Pieces: Shrimp with fewer than four or five whole segments [19].

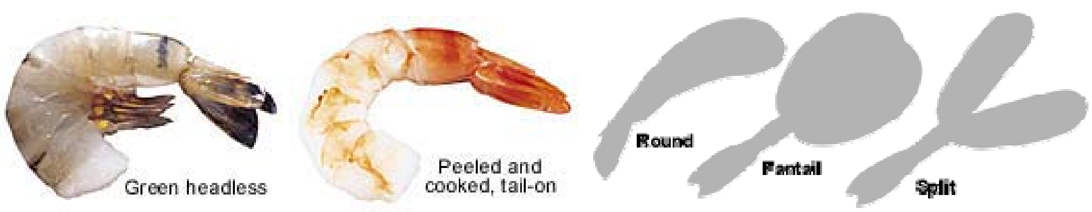


Figure 3. Primary shrimp product forms. Images from Seafood Business Seafood Handbook, 1999.

Frozen Products: Frozen shrimp generally comes in two forms: blocks (shrimp frozen en masse) and individually quick-frozen (IQF) packs [19]. Both shrimp blocks and IQF shrimp are glazed with a protective ice coating to prevent dehydration [19].

Breaded Shrimp: Shrimp, whether tail-on or tail-off, is the most-common breaded shellfish on the market [19].

Import and Export Sources and Statistics
About three quarters of world shrimp production is wild-caught. The remaining quarter of total production is farm-raised shrimp [5, 6]. In 2003, one study found that shrimp farming is growing at 12% to 15% per year (Clay 2003; Rosenberg 2003). Perhaps 50% of shrimp traded internationally are farm-raised (Clay 2003).

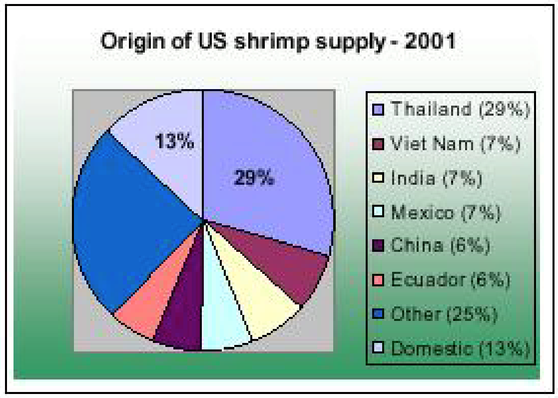
According to the latest figures available in 2003, about 87% of the U.S. shrimp supply was imported. This includes farmed and wild, warm- and coldwater-shrimp, and U.S. national import statistics do not distinguish between these categories (NMFS Statistics 2003).

On the world market, farmed shrimp is typically traded in boxes of 1 to 20 kilograms (Clay 2003). Although the pre-consumer market for farmed shrimp (from farm to wholesaler) tracks information about the species, size, and country of origin of each box of farmed shrimp (Clay 2003), marketers often remove this information before shrimp is sold at retail outlets, leaving the consumer with no easy way to discern the origins of their shrimp (Cutland and Cherry 2002). It is hoped that the advent of country-of-origin labeling (COOL) in autumn 2004 will help U.S. consumers discern the sources of their shrimp.

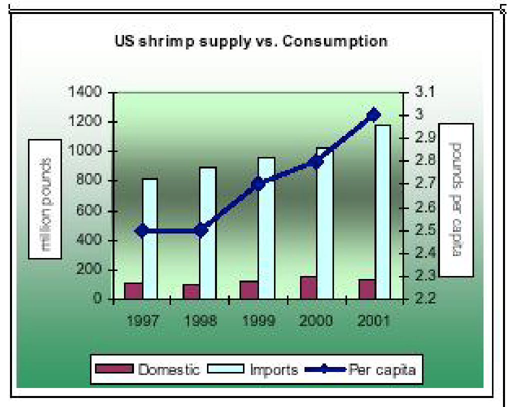
The U.S. imports more seafood than it exports; for several years, this trade deficit has been driven by what seafood market analyst H.M. Johnson calls "the tidal wave of shrimp imports" [5]. In 2000, imports of shrimp to the U.S. topped one billion pounds (heads-off weight) for the first time in history. That translates to 343,418 metric tons, with a wholesale value of about $3.7 billion. As of the latest figures available in 2003, about 87% of the U.S. shrimp supply was imported. This includes farmed and wild, warm- and coldwater-shrimp (Cutland and Cherry 2002). So-called "value-added" or processed shrimp products are an important part of the import picture. Between 1997 and 2000, imports of breaded shrimp increased by 85% and cooked shrimp by 23% [5].

In 2001, the total U.S. shrimp supply was about 1.3 billion pounds (589,670 metric tons), including domestic landings of about 180 million pounds (81646.6 metric tons) (Cutland and Cherry 2002). Domestic landings (of ***wild*** shrimp) thus accounted for about 13% of the U.S. shrimp market in 2001. The exact percentage of the market that is domestic ***farmed*** shrimp is unavailable in NMFS or FDA statistics (NMFS Stats 2003).

Shrimp has the unusual distinction of being the one seafood preferred equally in all regions of the United States (AquaNIC 2001). In 2001, for the first time in history, shrimp became the most-consumed seafood in the United States, as per-capita consumption of shrimp surpassed consumption of canned tuna (Johnson 2003). In 2001, Americans ate 3.4 pounds of shrimp per capita—an increase of 0.2 pounds from 2000 and 0.4 pounds from 1999 (Johnson 2003).



Source: National Marine Fisheries Service



Source: National Marine Fisheries Service/National Fisheries Institute

Figure 4. (L) Origin of U.S. shrimp supply; (R) Domestic shrimp production vs. consumption. Source: NMFS.

For many years (Johnson 2003; GLOBEFISH 2003), Thailand has been the leading import source for the U.S. (Figure 4). In 2001, Thai shrimp accounted for 29% of the U.S. market (Cutland and Cherry 2002). Mexico, India, and Vietnam tied for second place, with 7% each (Cutland and Cherry 2002). China, Indonesia, and Bangladesh also make substantial contributions to U.S. shrimp imports (Johnson 2003; NMFS 2003; Globefish 2003; Clay 2003). In all, Asian nations account for 66% of America's imported shrimp (Johnson 2003; NMFS 2003).

Consumption Information and Trends

Worldwide, shrimp consumption has been on the rise for more than a decade [25]. Demand for this luxury item shows no sign of slowing in the major markets of Japan, Europe and the United States. In the United States, shrimp has the unusual distinction of being the one seafood preferred equally in all regions of the country [9]. U.S. shrimp consumption rose in 2000 to 3.2 pounds per capita, up 0.2 pounds from 1999 [5]. These statistics, like for the global shrimp market, make no distinction between warmwater and coldwater shrimp, farm-raised or wild-caught. However, data show that about three-quarters of world shrimp production is wild-caught. The remaining quarter of total production is farm-raised shrimp [5, 6].

Trends in Farmed Shrimp Production

Worldwide, more than a million metric tons of farm-raised shrimp are produced each year; in 2003, one study found that shrimp farming is growing at 12% to 15% per year (Clay 2003; Rosenberg 2003). In 2000, farmed shrimp production topped 700,000 metric tons [9]; FAO reported approximately 1.1 million mt in 2001 and 1.6 mt in 2002 (Clay 2003). In total, about one-quarter of world shrimp production is farm-raised [5]. However, wild shrimp tend to be consumed in the country of catch, while farmed shrimp are more likely to be traded internationally (Clay 2003).

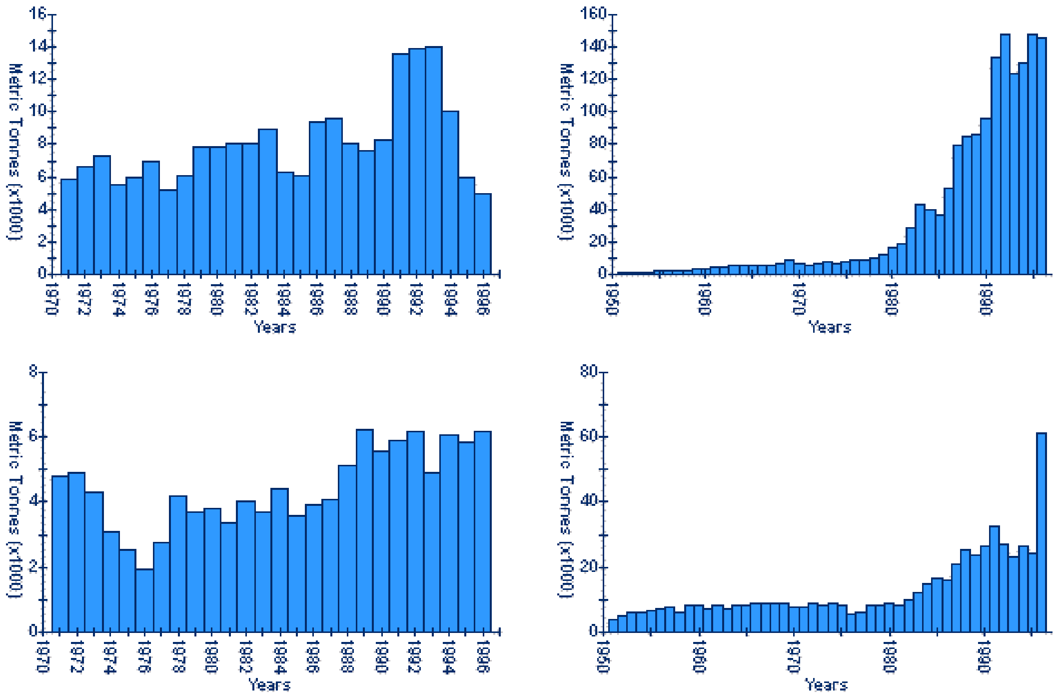


Figure 5. (TL) Total capture of Penaeus vannamei (wild-caught only); (TR) Total production of P.vannamei (wild plus farmed); (BL) Total capture of Machrobrachium rosenbergii (wild-caught only); (BR) Total production of M. rosenbergii (wild plus farmed). Graphs courtesy UN FAO FIGIS database.

Shrimp Aquaculture Information: International Shrimp Farming

Operation Types: International

Shrimp are most commonly cultivated in open-air ponds. At their simplest, these are enclosures of tidal estuary, ringed with earthen levees. Small postlarvae, often netted from the wild, are introduced into the ponds. In the simplest systems, the shrimp feed on algae and other ecosystem products (Clay 2003). In slightly more technological operations, supplemental food is introduced in the form of feed pellets. When the shrimp have grown to market size, a levee on the seaward side of the pond is opened. A net or other collector is installed over the outlet, releasing the water but trapping the shrimp [18].

More advanced systems line the bottoms of the ponds with clay to prevent wastes from seeping into the underlying soil and groundwater [18]. In Brazil, pond bottoms are often lined with plastic (Clay 2003). Further advances include the use of mechanical aeration, which enables more intensive stocking of the ponds; mechanical feeders, which standardize feedings; and various types of mechanical or biological filters to treat effluent when the ponds are drained [18].

Some facilities now specialize in breeding shrimp in captivity and supplying postlarvae to other farms. While this takes some of the pressure off wild shrimp populations, there is not enough broodstock cultivated to supply the worldwide demand [8].

In Thailand, the United States and Israel, a few shrimp farms employ fully enclosed systems that filter and recirculate their water. For the most part, these are still experimental efforts that do not yet supply much shrimp to the market [7, 11, 26].

Intensity of Cultivation: International

Shrimp can be cultivated in several different ways. Coastal ponds stock their shrimp at medium densities and often aerate the water mechanically; this is considered a "semi-intensive" form of aquaculture [27]. Recirculating inland systems stock their shrimp at high densities; this method requires more equipment and is considered "very intensive" [9]. In Latin America, most shrimp farms stock their ponds at low densities and manage without aeration [28]. In India, 80% of farmed shrimp come from small, marginal holdings which use a variety of culture techniques, ranging from traditional paddy culture to specially built ponds utilizing aerators, pellet feed dispensers, and other mechanical methods [29].

The limiting factor on shrimp density is often disease. In the early 1990's, two viral diseases (white spot and Taura syndrome) swept through Asia's shrimp farming industry [30]. Spread by infected broodstock, these diseases were soon detected in the Americas [30] and continue to threaten shrimp farms worldwide [26]. The highest densities of shrimp are achieved in high-tech recirculating freshwater systems, which start with pathogen-free postlarvae [26].

Type of Feed and Feed Conversion Ratio: International

As omnivorous scavengers, shrimp can feed on a wide range of protein sources, but large-scale shrimp aquaculture typically depends upon commercially formulated shrimp feeds [11]. These always contain fish meal as a source of protein, and often contain fish oil as a source of lipids (11; Clay 2003). Although marine and freshwater shrimp can be successfully cultivated on diets containing no fish meal or fish oil (SEAFeeds Workshop Report 2003), commercial shrimp typically contains fish derivatives. According to one authority, it currently takes between 1.7 and 2.21 kilograms of wild fish to produce one kilogram of farmed shrimp (Tacon, SEAFeeds Workshop Report 2003). However, Clay (2003) suggests that current ratios range from 1.4:1 to 2.0:1, and reports that super-intensive shrimp farms in Belize now use only 0.7 kg of wild fish to produce 1 kg of shrimp.

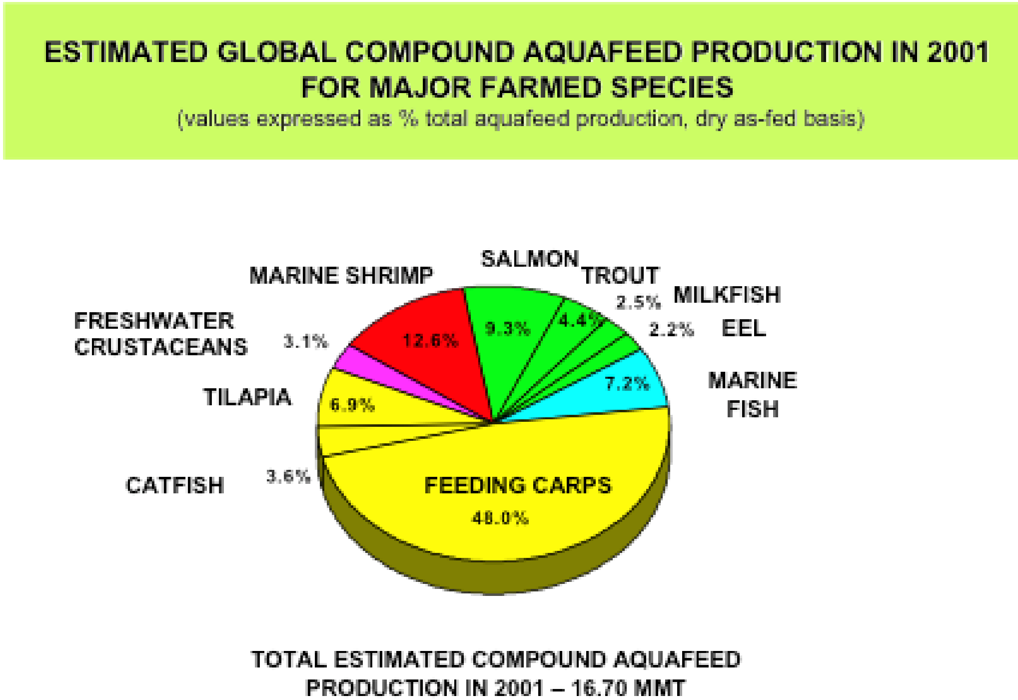
Because fish meal and oil are typically the most expensive ingredients in a compound feed (Tacon 2003), the fish-feeds industry is working to decrease the percentage of fish meal and fish oil in compound feeds (SEAFeeds Workshop Report 2003); this may explain why a review by Naylor et al. (2001) states that the average ratio of wild fish to farmed shrimp is 2.25 to 1 [31]. As can be seen from the tables below, in 2001, marine shrimp consumed about 12.6% of the total production of compound aquacultural feeds, into which went 19.3% of the world's fish meal and 7% of the world's fish oil (SEAFeeds Workshop 2003).

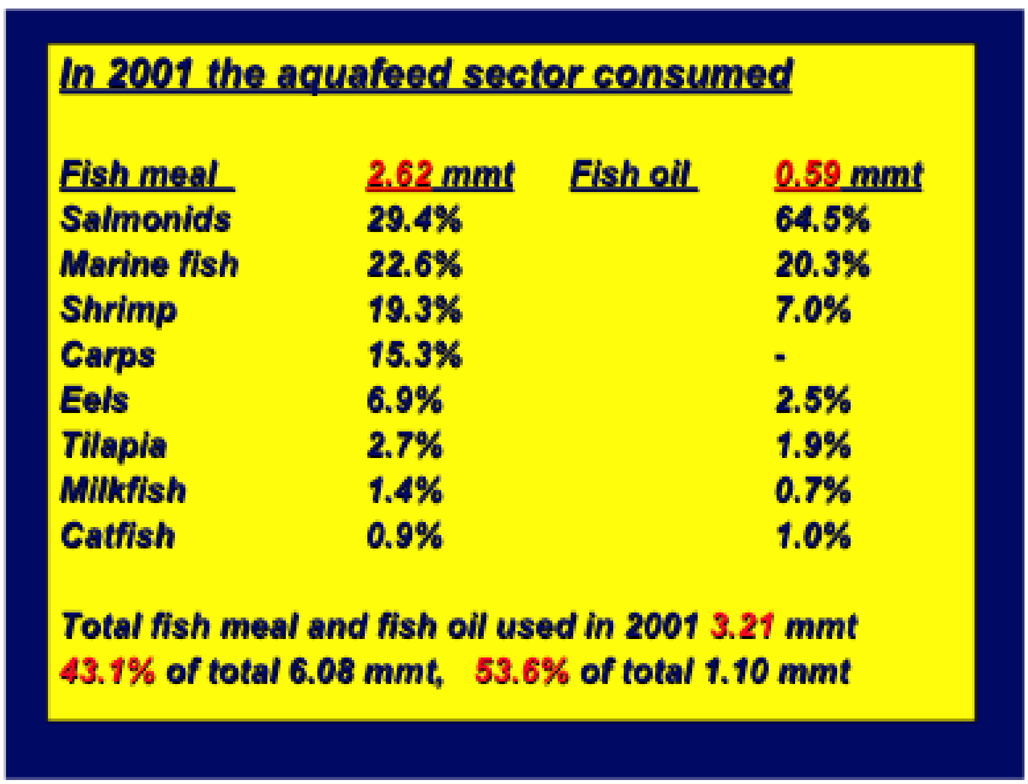
Species group	*Pelagic input per unit of production*
Eels	3.4-4.2
marine fish	2.9-3.7
Salmonids	2.6-3.3
marine shrimp	**1.7-2.1**
freshwater crustaceans	1.0-1.3
Milkfish	0.3-0.4
Catfish	0.3-0.4
Tilapia	0.2-0.3
feeding carp	0.1-0.2

Table 3. Conversion efficiency of captured fish to farmed fish (kg per kg fresh weight). From Tacon, SEAFeeds Workshop Report 2003.

Fish meal and oil is derived mostly from directed fisheries for small, sardine-like species; the major fishing nations are Peru, Chile, and the Scandinavian countries (SEAFeeds Workshop Report 2003). These are fast-breeding, short-lived, planktivorous fishes, probably well suited by their life history to support heavy fishing (SEAFeeds Workshop Report 2003). With the exception of one overfished stock of blue whiting, the fish stocks targeted for reduction fisheries are believed to be within safe biological limits (Pike 2003). The stocks should be considered fully fished, as total landings remain relatively constant (including predictable declines caused by El Nino) (Pike 2003).

The directed reduction fisheries are the world's largest source of fish meal, but not the only source. Fish meal may also be derived from fish taken as bycatch in other fisheries (Steiner 2003), or from fish trimmings from the processing of wild or farmed fish (SEAFeeds Workshop Report 2003). These sources have the potential to expand the availability of fish meal without increasing pressure on the sardine-like fishes (SEAFeeds Workshop Report 2003). In some areas of the world, including Canada, fish trimmings now supply a significant fraction of the fish meal used in aquacultural feeds (SEAFeeds Workshop Report 2003). However, public-health laws enacted in the wake of the "mad cow" disaster forbid the use of fish trimmings in fish feeds within the European Union (SEAFeeds Workshop Report 2003).





In 2001 the aquafeed sector consumed

Fish meal	*2.62 mmt*	*Fish oil*	*0.59 mmt*
Salmonids	*29.4%*		*64.5%*
Marine fish	*22.6%*		*20.3%*
Shrimp	*19.3%*		*7.0%*
Carps	*15.3%*		*-*
Eels	*6.9%*		*2.5%*
Tilapia	*2.7%*		*1.9%*
Milkfish	*1.4%*		*0.7%*
Catfish	*0.9%*		*1.0%*

Total fish meal and fish oil used in 2001 3.21 mmt
43.1% of total 6.08 mmt, 53.6% of total 1.10 mmt

Figure 6. Graphs from SEAFeeds Workshop Report (2003) detailing world production of compound feeds for aquaculture (above) and percentages of fish meal and oil used in the feeding of various farmed species (below).

Management and Monitoring: International
Shrimp farms are subject to the various laws and monitoring protocols of each country where shrimp are raised (GAA 1999). In many nations, laws for environmental protection may not exist, or, if they exist, may or may not be enforced [32]. In Bangladesh, illegal environmental destruction by large shrimp farming concerns has led to mass protests by displaced villagers, who clash, sometimes violently, with local authorities [33].

Environmental Impacts: International
A factor in favor of farm-raised shrimp is that their production involves no bycatch of sea turtles or mature fish. However, most farms in Asia and Central and South America rely upon wild-caught broodstock, as the supply of captive-bred broodstock is very limited (17; Clay 2003). And perhaps 5% of shrimp farms in developing nations still depend on wild-caught postlarvae (18; Clay 2003). While the capture of larvae has become a cottage industry in some economically disadvantaged coastal communities [18], larva fishing takes a heavy toll of bycatch of the youngest stages of many fish and invertebrates [6, 18].

On the issue of habitat damage, the story varies depending on where and how the shrimp is cultured [27]. To date, approximately 1.5 million hectares of coastal habitat (mangrove forests, marshes, salt flats and agricultural lands) have been converted to shrimp ponds [16]. Worldwide, about 10% of the loss of mangrove forests can be attributed to shrimp farming; that figure rises to 20% in certain areas (Lassen 2004). Hernandez-Cornejo and Ruiz-Luna (2000) reported little environmental impact for shrimp cultivated on barren salt flats of Mexico's Sinaloa coastline [27]. Trott and Alongi (2000) found that nutrients decreased to pre-cultivation levels within three years of the cessation of farming in certain Australian mangrove swamps where shrimp cultivation had not been intensive and the site enjoyed robust tidal flushing [34]. The rate of conversion of virgin wetlands to shrimp farms has slowed in recent years (Clay 2003). However, broadly speaking, in tropical nations, shrimp farming is associated with continuing reports of coastal habitat destruction [18, 27, 33]; displacement of small-scale sustainable fisheries [18, 33); harmful discharges of nutrient-enriched wastewater [11, 35]; and unregulated use of antibiotics [36].

In early 2002, the European Union banned imports of farmed shrimp from China, Indonesia and Vietnam because of antibiotic residues in the shrimp [38]. A 2002 analysis of the social and ecological sustainability of shrimp aquaculture in Thailand and Vietnam, conducted by the Royal Swedish Academy of Sciences, notes that, in Thailand, "years of experience with intensified systems...have not led to sustainable solutions" and concludes that "current pathways in both countries are unlikely to lead to a sustainable industry. A complete transformation of the way shrimp are grown, fed, processed, distributed, and regulated is needed" (Ambio 2002).

Experiments continue with inland shrimp farming in Thailand, Israel and elsewhere [26, 30]. Inland farms avoid any impact on coastal habitat, and may be sited in existing agricultural regions with no more impact to the environment than conventional farms [37]. Because of the strict need to protect the crop from disease in a recirculating system, these farms use pathogen-free captive-bred larvae as a matter of course [7, 11]. Recirculating systems entail relatively high production costs, but offer benefits of disease control, year-round production and wastewater containment.

Nation-By-Nation Overview of International Shrimp Farming

Clay (2003) notes that the environmental soundness of shrimp farms varies considerably from farm to farm, even more than it varies from nation to nation. Individual, progressive shrimp farms in Australia, Belize, Brazil, Madagascar, Mexico, and all Asian nations may equal or surpass the environmental friendliness of United States shrimp farms (Clay 2003). However, as U.S. shrimp markets typically preclude tracing shrimp back to its source farm, Seafood Watch is forced to make blanket recommendations based on generalized information about shrimp farming practices in various nations.

Australia: While Australia supplies only a small fraction of farmed shrimp imported into the U.S., environmental standards and enforcement in Australia are comparable to those in the United States (Clay 2003).

Bangladesh: In coastal Bangladesh, the black tiger prawn *P. monodon* is cultured in mixed-species ponds along with other shrimps (*P. indicus, Metapeneaus monoceros, M. brevicornis*) and several species of finfish (Alam and Phillips 2004). While the tiger prawn is the main product of these farms, accounting for 52% of crop biomass and about 89% of crop value, the raising of finfish along with shrimps has been a hedge for farmers when shrimp crops are lost due to viral disease (Alam and Phillips 2004).

Belize: Clay (2003) reports that a few super-intensive shrimp farms in Belize now use only 0.7 kg of wild fish to produce1 kg of shrimp.

Brazil: Brazil is the largest producer of farmed shrimp in the Western Hemisphere, harvesting 60,128 mt in 2002 (Nunes 2004). While most tropical shrimp farms can produce two or three crops per year, shrimp farms in Brazil average 3.5 crops per year (Clay 2003) and some report 3.8 crops per year (Jost 2004). Brazil's shrimp farming industry began in the early 1980s, but suffered setbacks due to disease outbreaks in the early 1990s. Currently, there is a trend away from low-intensity ponds where shrimp spend their entire life cycle to high-intensity operations with specialized nursery tanks for postlarvae and lined ponds for adults (Nunes 2004). These intensified operations depend upon paddlewheel aerators (Nunes 2004). Such modifications help minimize the spread of disease. In order to maximize feed-conversion ratios and minimize nutrient pollution of ponds and groundwater, Brazilian shrimp farmers are moving away from broadcast feeding to the use of feeding trays (Nunes 2004).

China: Total production of 380,000 mt in 2002 (Wang et al. 2004). In 2002, shrimp farms were estimated to cover 240,000 hectares, with average yield per hectace about 1.6 tons (Wang et al. 2004). Traditionally, semi-intensive farming along coastlines used *Penaeus chinensis.* Farming began in the late 1970s and burgeoned along the coast until severe outbreak of white-spot disease in 1993. Farming declined for some years, but has recovered with introduction of disease-resistant *P. vannamei*. There has been a recent expansion of intensive industrial indoor ponds, especially in Shandong Province. Indoor ponds are now estimated to cover 10,000-15,000 hectares and to produce 90,000-100,000 mt annually (Wang et al. 2004). Currently, the species profile of Chinese-produced famed shrimp is: *P. vannamei* 60%; *P. chinensis* 15%; *M. japonicus* 15%; *P. monodon* 8%, and other species 2% (Wang et al. 2004).

Ecuador: A major outbreak of viral disease decimated Ecuador's coastal shrimp farms in 1999. By 2001, shrimp production had dropped 70% from its 1998 level (Alava 2004). Since 1999, shrimp farming has been expanding inland as an alternative to the coastal zone. About 90% of Ecuador's inland shrimp farms are in Guayas province, and many are located on the sites of old freshwater red-claw lobster pond farms (Alava 2004). In these inland areas, *P. vannamei* are raised in very low-salinity conditions (i.e., hard groundwater). Ecuador has an environmental permitting process in place to address impacts of these inland farms on groundwater, surface water, and agricultural lands (Alava 2004). One study found relatively major impacts on vegetation and soil erosion during construction and operation of these inland shrimp farms, and moderate to low impacts on groundwater and surface water (Alava 2004).

Honduras: The leading shrimp producer in Central America, Honduras shrimp farming began in 1972 and expanded throughout the 1980s (Valderama and Engle 2002). In the early 1990s, problems with Taura virus, introduced from Asia (probably with infected broodstock) eroded the profitability of the operations (Valderama and Engle 2002). Introduction of Taura-resistant lines and use of antibiotics restored productivity, and production peaked in 1998 at 12,000 mt of shrimp from 14,000 hectares of pond (Valderama and Engle 2002). However, introduction of the white-spot virus in 1999 has curbed production once again (Valderama and Engle 2002). The heart of Honduras' shrimp farming industry is the Gulf of Fonesca, near Choluteca (Valderama and Engle 2002; Marquez 2001). The rapid expansion of shrimp farming in this area is associated with destruction of mangrove forests, despite legal protection for mangrove habitat under Honduran law (Marquez 2001). Heavy seasonal discharges of wastewater from shrimp ponds into the ocean, as well as ongoing discharges of wastes from shrimp packing plants, also violate Honduran law, but no enforcement efforts are made (Marquez 2001). One very large Honduran farm, Sea Farms International, is responsible for 50% of the national production; this operation reports feed-conversion ratios of 1.5:1 (Gautier et al. 2003) and claims to replant mangroves for their biofiltering benefits (Gautier et al 2003). Sea Farms International operates over 7,000 hectares of shrimp ponds in low-density, non-aerated production. The ponds are lightly fertilized with nitrogen and phosphorus; a water-quality monitoring program run by the shrimp farming industry found no change in the nutrient content of the Gulf of Fonesca between 1993 and 2003 (Gautier et al 2003).

Mexico: Please see the Seafood Watch Farmed Mexico shrimp report at www.montereybayaquarium.org for a more detailed analysis of Mexico farmed shrimp.

Philippines: Disease has had a severe impact upon Philippine shrimp farming: from a high of 90,426 mt in 1994, production had declined to 35, 493 mt in 2003 (Yap and

Villaluz 2004). Surviving, successful farms tend to have the following characteristics and use the following culture practices: access to clean seawater, either by being located close to shorelines that drop off into deep water, or by having access to a saltwater well, or by treating new seawater in a reservoir; a clean and compact pond bottom, kept clean and compact either by being located above the tide line or by being heavily backfilled with crushed limestone; use of health-tested postlarvae; adequate aeration of the ponds; "good feed management"; addition of bio-remediators to the ponds, such as fish and/or probiotic microbes; letting ponds sites dry out thoroughly between shrimp crops or else alternating shrimp with crops of tilapia or milkfish; "adequate production-based incentives to technicians and workers" (Yap and Villaluz 2004).

Peru: Peru's cold climate limits shrimp farming; perhaps 3,000 hectares are available for shrimp farming (Moya et al. 2004). The disease epidemics of the late 1990s have hit the Peruvian industry particularly hard, and perhaps 50% of the shrimp ponds constructed in the past decade are now idle (Moya et al. 2004). Farmers pursue one of two strategies to defeat disease: stocking extensive areas at low densities, or enclosing small lined ponds under greenhouses and conducting intensive, high-density aquaculture with disease-free postlarvae (Moya et al. 2004). In these intensive indoor systems, which are always intensively aerated, water exchange varies from zero to 12% per day (Moya et al. 2004).

Thailand: Please see the Seafood Watch Farmed Thailand shrimp report at www.montereybayaquarium.org for a more detailed analysis of Thailand farmed shrimp.

Vietnam: Shrimp farms currently cover 400,000 hectares of Vietnamese land, mostly in South Vietnam (Phuong 2004). Seventy percent of this land is employed in "extensive" farming; i.e., low-density open pond culture (Phuong 2004). A report by the Environmental Justice Foundation asserts that, since 1975, Vietnam's Mekong Delta has lost 70% of its mangrove habitat due to the expansion of shrimp farming (EJF 2001). This assertion is questioned by Clay (2003), who states that the wartime use of the defoliant Agent Orange has been the single largest cause of mangrove loss in Vietnam. Vietnam produces only 30% of the shrimp postlarvae used by its industry (Phuong 2004). Most of the "extensive" farms rely on wild postlarvae (Phuong 2004). In extensive farming, the shrimp are stocked at low densities; shrimp tend to feed on algae and microorganisms that develop naturally in the ponds, and inputs of feed or chemicals to the ponds are very low (Phuong 2004). Some farmers practice so-called "improved extensive" farming, where shrimp crops alternate with rice in flooded fields (Phuong 2004). However, the use of semi-intensive and intensive farming methods is expanding rapidly in Vietnam. These entail high production costs, but can maximize profits, if disease does not wipe out the crop (Phuong 2004). Shrimp farming is still expanding rapidly in Vietnam's coastal areas, but the infrastructure for shrimp health monitoring is still underdeveloped (Phuong 2004). Seed stock is in short supply, and viral infections are on the rise (Phuong 2004). In some areas, 40% of each shrimp crop is lost to viral disease (Phuong 2004). Use of antibiotics is widespread (Phuong 2004).

Synthesis and Analysis of Criteria: International Farmed Shrimp

Effects on Wild Fisheries

Does the aquaculture activity adversely impact wild fisheries?

a) Introduction of non-indigenous species and/or pathogens

Shrimp farming has spread viral shrimp diseases around the globe [25, 29]. In some areas, stocks of non-native shrimp have become established—e.g., as a result of escapes from shrimp farms, Pacific white shrimp are now found in the Gulf of Mexico (Steiner 2003). Their impact upon the ecosystem is unknown. In other areas, such as around the Hawaiian archipelago, establishment of feral shrimp populations is unlikely because suitable estuary breeding habitat for penaeids does not exist (Dalzell 2003).

b) Collection of wild broodstock and postlarvae

Most farms in Asia and Central and South America rely upon wild-caught broodstock, as the supply of captive-bred broodstock is very limited (17; Clay 2003). And perhaps 5% of shrimp farms in developing nations still depend on wild-caught postlarvae (18; Clay 2003). While the capture of larvae has become a cottage industry in some economically disadvantaged coastal communities [18], larva fishing takes a heavy toll of bycatch of the youngest stages of many fish and invertebrates [6, 18].

c) Wild-caught Food

Many small-scale shrimp farms in developing nations do not use commercially formulated shrimp feeds. This means that their reliance on fish meal from wild fish is less than that of large-scale shrimp farming operations [14]. However, large-scale shrimp farming operations in Asia, Central America and South America do rely upon commercially produced feeds [14]. Fish meal is always a component of these rations (Clay 2003). Naylor et al. (2001) reported a typical ratio of 2.25 kilos wild fish (wet weight) to produce each kilo of shrimp (wet weight) [31]. But industry may have improved upon this ratio in the past few years. According to one authority, it currently takes between 1.7 and 2.21 kilograms of wild fish to produce one kilogram of farmed shrimp (Tacon, SEAFeeds Workshop Report 2003). However, Clay (2003) suggests that current ratios range from 1.4:1 to 2.0:1, and reports that super-intensive shrimp farms in Belize now use only 0.7 kg of wild fish to produce 1 kg of shrimp. The actual environmental impact of reduction (fish meal- directed) fisheries remains unquantified. With the exception of one overfished stock of blue whiting near Scotland, world stocks of reduction fishes are considered fully fished and at sustainable levels of abundance (Pike 2003). Ironically, in Asia, some of the fish meal fed to farmed shrimp is made from the incidental catch (bycatch) taken in local trawl fisheries for wild shrimp (Steiner 2003). This connects shrimp farming in these regions to the trawl fisheries implicated in the decline of endangered sea turtles (Steiner 2003).

Environmental and Ecological Impacts

Does the aquaculture activity impact environmental health and productivity?

a) Habitat modification

Broadly speaking, international shrimp farming is associated with continuing reports of habitat degradation, particularly in coastal regions of Southeast Asia and India

[17,26,32]. Coastal shrimp farming in Asia and South America has been associated with the displacement of small-scale sustainable fisheries that rely upon intact coastal habitat [17, 32].

b) Effluent discharge
Broadly speaking, international shrimp farming is associated with continuing reports of nutrient effluent discharge [14, 32] as well as the unregulated use of antibiotics banned in the United States and European Union [35, 38]. However, there has been progress in recent years in many nations in the use of settlement ponds and "biofilters" (crop plants or artificial wetlands) to reduce sediment discharge and nutrient pollution from shrimp farms (Clay 2003).

c) Food web interactions
The direct effect upon ocean food webs of the capture of fish for shrimp feed is unknown. Many developing-world shrimp farms depend on wild-caught postlarvae to stock their ponds. While the capture of larvae has become a cottage industry in some economically disadvantaged coastal communities, larva fishing takes a heavy toll of bycatch of the youngest stages of many fish and invertebrates [17, 24].

Consumer Information
International farmed shrimp account for about 25% of all shrimp produced [9, 24] and for 45–50% of shrimp traded internationally (Clay 2003). The largest producers are Thailand, China, and India [13], and the largest suppliers to the U.S. are Thailand, India, and Mexico [9]. Because shrimp is traditionally sold in the U.S. without regard to species, nation of origin, or catch/culture method, it is currently nearly impossible for the consumer to discern international farmed shrimp in the market [9]. It is hoped that the advent of country-of-origin labeling (COOL) in autumn 2004 will help U.S. consumers discern the source of their shrimp.

List of Component Ranks	**Low Conservation Concern**	**Medium Conservation Concern**	**High Conservation Concern**	**Critical Conservation Concern**
Feed Efficiency		√		
Risks to Wild Stocks		√		
Disease Transfer		√		
Habitat Effects			√	
Pollution		√		
Chemical Use		√		
Management Effectiveness			√	

Overall Seafood Rank: Avoid

Seafood Watch Recommendation for International Farmed Shrimp

International farmed shrimp are ranked as Avoid.

Shrimp Aquaculture Information: United States

Operation Types: United States
Shrimp farming in the United States is comparatively small-scale. All told, shrimp farms cover only about 600 acres in the U.S. (Clay 2003). In their 1999 monograph "Codes of Practice for Responsible Shrimp Farming", the Global Aquaculture Alliance concludes that, compared to Asia and South and Central America, the United States will always be a minor producer of farmed shrimp because of high production costs, few suitable sites, and its relatively cool climate (GAA 1999). Nonetheless, the enormous value of shrimp leads to ongoing attempts to expand U.S. shrimp aquaculture.

U.S. shrimp farmers have access to advanced technology and tend to farm with more machinery than farmers in Asia or South America (GAA 1999). U.S. shrimp farms are usually seawater coastal pond culture or low-salinity inland pond culture (Stickney 2002), with a few high-tech enclosed systems in use inland [7, 11, 26].

Some penaeid species, among them the Pacific white shrimp *Penaeus vannamei*, the Chinese white shrimp *P. chinensis*, and the black tiger prawn *P. monodon*, can adapt to water much less saline than seawater [7, 10, 11]. This allows raising of shrimps in non-seawater systems—often in groundwater. In certain areas, groundwater contains all the minerals needed by the shrimp. In other areas (such as the southern United States) the mineral profile of groundwater is very different than seawater of the same salinity (Green 2004). In the U.S. states of Arkansas and Alabama, shrimp farmers have learned to supplement groundwater with trace minerals to allow *P. vannamei* to thrive (Green 2004; Davis et al. 2004).

Intensity of Cultivation: United States
Coastal ponds stock their shrimp at medium densities and often aerate the water mechanically; this is considered a "semi-intensive" form of aquaculture [27]. Recirculating inland systems stock their shrimp at high densities; this method requires more equipment and is considered "very intensive" [9] or "super intensive" (Clay 2003).

The limiting factor on shrimp density is often disease. In the early 1990s, two viral diseases (white spot disease and Taura syndrome) swept through Asia's shrimp farming industry [30]. Spread by infected broodstock, these diseases were soon detected in the Americas [30]. These viral diseases put several Texas coastal farms out of business (Stickney 2002) and continue to threaten shrimp farms worldwide [26]. The highest densities of shrimp are achieved in high-tech enclosed freshwater systems, which start with pathogen-free postlarvae [26].

Type of Feed and Feed Conversion Ratio: United States
All U.S. shrimp farms use commercially formulated shrimp feeds [11] (Stickney 2002). Fish meal is always a component of these rations (Clay 2003). Naylor et al. (1999) reported a typical ratio of 2.25 kilos wild fish (wet weight) to produce each kilo of shrimp (wet weight) [31], but this value may have been improved upon by industry. According to one authority, it currently takes between 1.7 and 2.21 kilograms of wild fish to produce

one kilogram of farmed shrimp (Tacon, SEAFeeds Workshop Report 2003). However, Clay (2003) suggests that current ratios range from 1.4:1 to 2.0:1, and reports that super-intensive shrimp farms in Belize now use only 0.7 kg of wild fish to produce 1 kg of shrimp. There is no reason to suspect that feed efficiencies in U.S. practice are very different from those found in international surveys. Please see the feed conversion discussion in the International section (above) for a fuller elaboration. It cannot be overemphasized: the feed conversion ratios above are "wet fish weight to wet shrimp weight", not feed weight to shrimp weight.

CEATECH's Kauai Shrimp Farm, based on Kauai, Hawaii, states an institutional objective of producing shrimp in the most ecologically sustainable way possible (see Seafood Watch Kauai Shrimp Evaluation for references). CEATECH's techniques can reasonably be considered best practices among shrimp farms *currently in commercial production* in the United States. Kauai reports feed conversion ratios of about 2.1 to 1. Since Kauai uses a shrimp feed containing about 35% "protein meal", which is itself a mixture of fish and soy proteins, this indicates a dry-weight protein conversion ratio that cannot be "worse" than 0.735 to 1 (if all the protein were derived from fish meal). At a standard wet-weight to dry-weight ratio of 4:1 (Clay 2003), this worst-case scenario would mean a wet fish to wet shrimp feed conversion ratio of 2.94 to 1. Again, such would be the case ***if*** all the protein in Kauai's feed were derived from fish meal. As we know, some fraction of the formula is soy protein; as fish meal is the most expensive component of shrimp feeds, feed makers are always trying to minimize fish meal content (Clay 2003; Stickney 2002; Tacon 2003).

Management and Monitoring: United States
In the United States, shrimp farms are subject to EPA water quality regulations, which are enforced by state fisheries agencies and/or state pollution control agencies [30]; (Stickney 2002; Treece 2002). Overall, regulations are more sophisticated and compliance is better in the United States than in many other nations (Clay 2003).

Environmental Impacts: United States
Pond culture of saltwater shrimp in the U.S. started in the late 1960s and expanded in the early 1970s [9]. Coastal shrimp farms in the U.S. are more closely regulated (or more strictly enforced) than the farms of many other nations (37, 38; Clay 2003). Because foreign farmed shrimp is often much cheaper than domestically raised shrimp, the U.S. shrimp farming industry faces constant economic challenges.

U.S. farmed shrimp avoid the worst environmental excesses of the tropical farms. Besides tighter regulation and better enforcement of environmental law, U.S. shrimp farmers are subject to pressure from citizens' groups about environmental impacts [38]. In their own economic interest, U.S. shrimp farmers continue to experiment with new technologies to increase efficiency and minimize the environmental impact of their operations (37; Clay 2003). In addition, U.S. farms use captive-bred shrimp larvae [7, 9].

Experiments continue with inland shrimp farming in the United States and elsewhere [26, 30]. Several U.S. producers are experimenting with low-emission, enclosed freshwater culture systems [7, 11, 26]. Inland farms avoid any impact on coastal habitat and may be sited in existing agricultural regions with no more impact to the environment than conventional farms [37]. Because of the strict need to protect the crop from disease in a recirculating system, these farms use pathogen-free captive-bred larvae as a matter of course [7, 11]. Recirculating systems entail relatively high production costs, but offer benefits of disease control, year-round production and wastewater containment. Recirculating systems are drawing more and more interest from U.S. shrimp farmers [37].

State-By-State Overview of U.S. Shrimp Farming Operations

Most U.S. farmed shrimp is raised in Texas (Stickney 2002; Treece 2002). There are a few operations in the states of Hawaii, Florida, South Carolina, and Kentucky (Stickney 2002; Treece 2002; Clay 2003). Very recently, shrimp farming has been introduced to the inland delta regions of Mississippi and Alabama (Stickney 2002; Treece 2002; Clay 2003). A few experimental efforts are underway in Arizona and other states.

Alabama: Very recently, shrimp farming has been introduced to the inland delta regions of Mississippi and Alabama, traditional strongholds of catfish farming (Stickney 2002; Treece 2002; Clay 2003). The lime-rich water of this area provides enough mineral content to support shrimp species, such as *P. vannamei*, that can adapt to low-salinity waters (Stickney 2002). The ecosystems of these areas are able to support nutrient-rich pond culture of catfish, and no additional impact has been noted from the shrimp farms (Stickney 2002). Inland shrimp farming began in Alabama in 1999 with the conversion of a catfish fingerling pond to production of *P. vannamei* (Davis et al. 2004). In 2001, there were five producers covering a total of about 25 hectares, all in west-central Alabama (Davis et al. 2004). Alabama shrimp producers find that they must supplement their pond water with minerals, especially potassium, to obtain commercially viable harvest levels. Alabama shrimp farmers have an advantage in that they can piggyback on feed, equipment and loan infrastructures already in place for catfish farming (Davis et al. 2004).

Arizona: Four farms produced 175 metric tons of shrimp from 123 hectares of ponds in 2003 (Wilkenfield et al. 2004). Most ponds are dirt-lined and stocked at low densities (Wilkenfield et al. 2004). Shrimp farming began in Arizona only in 1998; producers hoped to take advantage of cheap land and abundant sunshine. Production has fallen in recent years because of low prices for shrimp and high operating costs. Arizona shrimp farmers are struggling with algal blooms, seasonal temperature fluctuations, and shrimp mortality caused by improper mineral balance in the water (Wilkenfield et al. 2004). Each Arizona producer is struggling to find a niche market to sustain itself (Wilkenfield et al. 2004).

Arkansas: Small amounts of shrimp are being pond-raised in Arkansas. The mineral content of Arkansas groundwater is different from seawater of the same salinity, requiring farmers to supplement their ponds with minerals (Green 2004).

Florida: In 2001, the last year for which figures are available, Florida had 13 shrimp farms covering a total area of 36 acres (Adams, Sweat and Martinez 2004). Total acreage was expected to rise to 170 acres in 2002. Florida farms produced both postlarvae and table-sized shrimp. Both outdoor ponds and enclosed raceway systems were in use (Adams, Sweat and Martinez 2004).

Hawaii: Two large commercial shrimp operations producing shrimp for the national market, several smaller farms producing pathogen-free broodstock, and a few local low-density ponds producing shrimp for local consumption make up Hawaii's shrimp farming industry. Please see the Seafood Watch Hawaii Farmed Shrimp Report for a fuller discussion. State water quality agencies report little or no problem with pollution or habitat degradation from Hawaiian shrimp farms (Tomomitsu 2002; Young 2003). One of the two large commercial operations is Ceatech's Kauai Shrimp Farm, which employs environmentally-friendly best practices including an inland location, antibiotic-free organic culture methods, and settling ponds for wastes. Seafood Watch has rated Ceatech's Kauai shrimp a "Best Choice". Please see the Seafood Watch Kauai Shrimp Farm Evaluation Report for a fuller discussion.

Mississippi: Very recently, shrimp farming has been introduced to the inland delta regions of Mississippi and Alabama, traditional strongholds of catfish farming (Stickney 2002; Treece 2002; Clay 2003). The lime-rich water of this area provides enough mineral content to support shrimp species, such as *P. vannamei*, that can adapt to low-salinity waters (Stickney 2002). The ecosystems of these areas are able to support nutrient-rich pond culture of catfish, and no additional impact has been noted from the shrimp farms (Stickney 2002).

Puerto Rico: There are few sites suitable for shrimp farming in Puerto Rico. Production has declined steadily from 200 mt in 1992 to 47 mt in 1997. This decline is partly due to the failure of a large prawn-raising operation in the early 1990s. Currently, just one large operation, Eureka Marine, is in place in Puerto Rico. In 1997, the last year for which figures are available, this farm produced 47 mt of shrimp from 30 hectares of lined ponds. Species raised include *Macrobrachium* prawns and other non-native shrimps (Alston & Cabarcas-Nunez 2004).

South Carolina: The climate of South Carolina restricts shrimp farmers to one crop per year (Stokes, Browdy & Atwood 2004). Unable to compete with inexpensive imported shrimp, many South Carolina shrimp farms have now converted to crayfish (Clay 2003). In 2003, there were ten shrimp farming operations in the state, covering 75 hectares of ponds, 20 hectares of impoundments, and two (indoor) greenhouse raceway intensive-production facilities (Stokes, Browdy & Atwood 2004). Seven of the ten growers raise captive-bred *P. vannamei* as table shrimp, while three raise wild-caught Atlantic white shrimp (*P. setiferus*) to sell as bait (Stokes, Browdy & Atwood 2004). The pond and impoundment farms are located at the coast and draw salt water from coastal creeks (Stokes, Browdy & Atwood 2004). Because of the expense of coastal land for siting open-pond shrimp farms and the glut of inexpensive foreign-farmed shrimp, plus the short growing season and the risk of losing crops to disease, the only segment of the shrimp farming industry expanding in South Carolina is indoor intensive greenhouse culture. Raceways can be sited on inexpensive inland property. Properly run with high-health postlarvae, raceways can produce three or four crops per year (Stokes, Browdy & Atwood 2004).

Texas: Currently, most U.S. shrimp is farmed along the south coast of Texas (Stickney 2002; Treece 2002). In the mid-1990s, there was some concern about environmental degradation associated with wastewater discharges from shrimp farms along the South Texas coast [8, 38]. Farms along the Arroyo Colorado coast were granted unlimited water-use rights by the state of Texas (Stickney 2002) and used this water to produce shrimp at high densities, pumping large amounts of seawater from the bay and discharging equal amounts of wastewater laden with sediment and nutrients (Stickney 2002). Local homeowners and dock owners soon complained; after investigation by Texas pollution control authorities, the farms were cited and their water ration was cut (Stickney 2002). These farms elected to stay in business by switching to recirculating systems, retrofitting their water intake canals as settling ponds and lowering their stocking density of shrimp. In 2002, these farms were still producing shrimp with little impact on the local environment (Stickney 2002). In 2004, a company based in the inland west-Texas town of Imperial began nationwide marketing of shrimp farmed in water from an underground saltwater aquifer (Permian Sea Shrimp 2004). This inland, closed-system farm appears to be one of the innovative shrimp farms applying the best available technology to produce an environmentally friendly product.

Synthesis and Analysis of Criteria: U.S. Farmed Shrimp

Effects on Wild Fisheries

Does the aquaculture activity adversely impact wild fisheries?

a) Introduction of non-indigenous species and/or pathogens

In some areas, stocks of non-native shrimp have become established—e.g., as a result of escapes from shrimp farms, Pacific white shrimp are now found in the Gulf of Mexico (Steiner 2003). Their impact upon the ecosystem is unknown. In other areas, such as Hawaii, establishment of feral shrimp populations is unlikely because suitable estuary breeding habitat for penaeids does not exist (Dalzell 2003). Shrimp farming has spread viral shrimp diseases around the globe [25, 29]. The white spot and Taura viruses have been detected in wild Gulf of Mexico shrimp [25]. So far, researchers have noted no effect of these viruses upon the overall health of the wild populations [25]. It is not known with certainty that these viruses escaped from captive shrimp, but some consider it likely, as the viruses seem to have originated in Asia [29].

b) Collection of wild seed stock

U.S. shrimp farmers do not use wild seed stock [10, 12].

c) Use of wild-caught food

U.S. shrimp farmers rely on commercially-formulated shrimp feeds [14]. While fish meal is often a component of these rations, the impact on wild fisheries remains unquantified. The typical conversion ratio is between 1.7 and 2.1 kg of wild fish (wet weight) per kg of farmed shrimp produced (wet weight) (Tacon, SEAFeeds Workshop Report 2003). The actual environmental impact of reduction (fish meal-directed) fisheries remains unquantified, although, with the exception of one overfished stock of blue whiting near Scotland, world stocks of reduction fishes are considered fully fished and at sustainable levels of abundance (Pike 2003).

Environmental and ecological impacts

Does the aquaculture activity impact environmental health and productivity?

a) Habitat modification

In the United States, habitat modification for shrimp farming has been very minor (Stickney 2002; Tomomitsu 2002; Young 2003). The climate and costs prohibit widescale development of shrimp farms in the U.S. (GAA 1999), with the result that this industry has little environmental impact.

b) Effluent discharge

There has been little problem with effluent discharge or nutrient pollution from shrimp farms in Hawaii (Tomomitsu 2002; Young 2003). Problems with effluent discharge along the Texas coast, the U.S.'s largest shrimp-producing area, have been largely solved by the introduction of recirculating techniques (Stickney 2002).

c) Food web interactions

The direct effect upon ocean food webs of the capture of fish for shrimp feed is unknown.

Consumer Information

In the United States, shrimp is traditionally marketed without regard to species, nation of origin, or catch/culture method. Because of this, it is nearly impossible for the consumer to select U.S. farmed shrimp in the market [9]. Even Texas shrimp packers mix wild-caught with farmed, and international with domestic, when processing shrimp in the United States' most important shrimp- farming region (Stickney 2002).

U.S. Farmed Shrimp (general recommendation): Proceed with Caution

List of Component Ranks	Low Conservation Concern	Medium Conservation Concern	High Conservation Concern	Critical Conservation Concern
Feed Efficiency		√		
Risks to Wild Stocks	√			
Disease Transfer	√			
Habitat Effects		√		
Pollution		√		
Chemical Use	√			
Management Effectiveness		√		

Seafood Watch Recommendation for U.S. Farmed Shrimp

Coastal-farmed U.S. shrimp are ranked as Proceed with Caution. Shrimp produced in the U.S. in enclosed inland systems could be a Best Choice.

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